# On-Blade Control of Rotor Blade Vibration

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High levels of vibration in rotorcraft fuselages cause various problems, including structural fatigue, pilot fatigue, reduced rotorcraft readiness, and increased costs of development and maintenance. Current helicopters typically employ *passive* vibration isolation and absorption to reduce fuselage vibration. However, these passive devices are heavy and have various other limitations. Past attempts to further reduce vibration have used *active* techniques such as higher harmonic control of the swashplate and individual blade control by means of active pitch links at the root of each blade. Modern "smart" materials provide an opportunity for on-blade active control, possibly for reduced weight and power. A small-scale, two-bladed rotor with on-blade control surfaces (elevons) was previously designed, fabricated, and tested in hover. The objective of the current project was to test this active rotor in a wind tunnel to determine the effectiveness of the elevon in changing vibratory blade moments in forward flight.

The active rotor is shown in the Ames 7- by 10-Foot Wind Tunnel in the first figure. The model is a two-bladed, 7.5-foot-diameter hingeless rotor that was operated at tip speeds of up to 298 feet/second. Each blade has one 10%-chord, 12%-span elevon that is actuated by two lead zirconate titanate (PZT) bimorphs; a close-up of the active section is shown in the second figure. A command voltage can be applied to the PZT in order to oscillate the elevon at the desired frequency.

The PZT actuator produced average elevon motions exceeding ±5 degrees for frequencies up to four times the maximum rotor speed of 760 revolutions per minute (rpm). The effectiveness of the elevons was measured by varying the elevon phase for five harmonics of the rotor speed (1/rev–5/rev) and recording the vibratory bending and torsion moments at the root of each blade. These phase sweeps were performed at various flight conditions, including low to moderate thrust levels, flight speeds

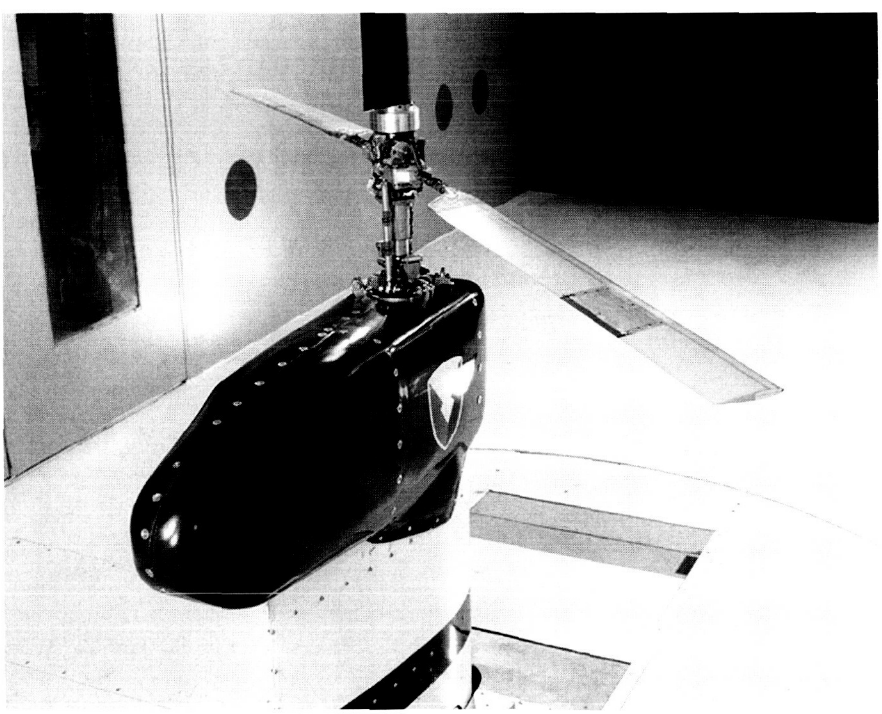

*Fig. 1. Rotor with on-blade elevons in the Ames 7- by 10-Foot Wind Tunnel.*

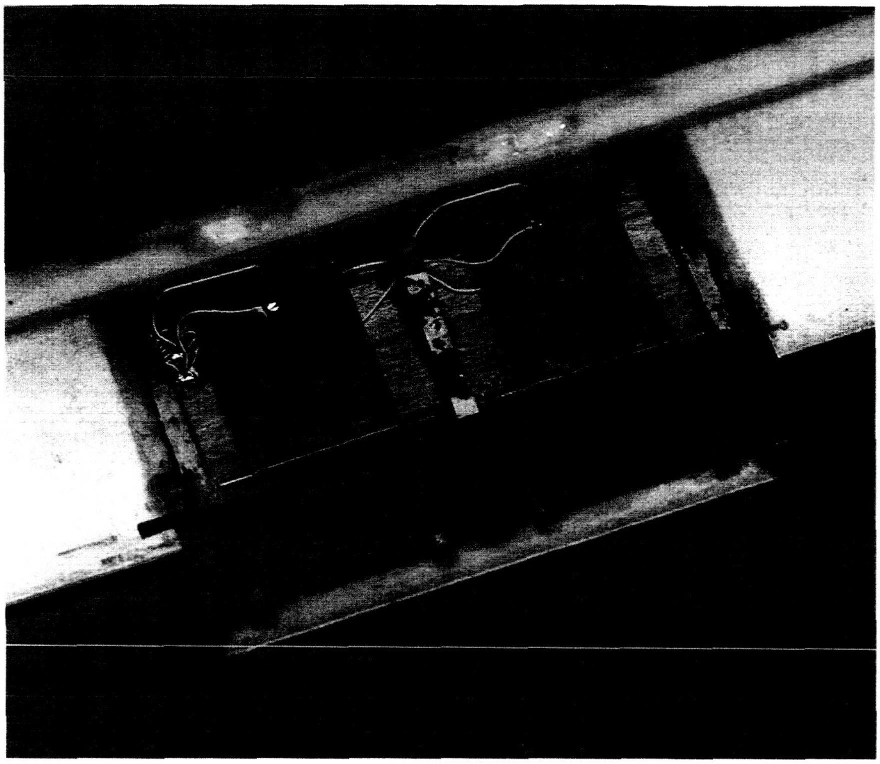

*Fig. 2. Close-up of the active section with the access panel removed and the elevon disassembled.*

up to 89 feet/second (or 30% of the maximum tip speed), and rotor speeds between 450 and 760 rpm. Changing the rotor speed allowed higher blade loadings, as well as an investigation of the effect of blade aeroelastic properties on elevon effectiveness. The resultant blade-frequency and aeroelastic coupling changes were expected to alter the elevon effectiveness at various harmonics of the rotor speed.

It was shown that the elevon could significantly change blade-root vibratory moments. High-speed effects on actuator performance and elevon effectiveness were measured up to a flight speed of 106 feet/second (or 60% of the tip speed) at essentially zero thrust and 450 rpm. The optimum phase angle for vibratory moment reduction was determined for 1/rev–5/rev excitation. Finally, the optimum amplitude of elevon motion was determined for selected cases. In summary, this project has provided an improved understanding of this on-blade control idea and has shown that on-blade active control holds promise for reducing helicopter fuselage vibration.

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